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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART III LEAD LINING

(Third Reprint NOVEMBER 1988)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 7 *September* 1970

Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART III LEAD LINING

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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART III LEAD LINING

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 15 October 1969, after the draft finalized by the Chemical Engineering Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 This standard is being issued in many parts. The lead lining of vessels and equipment is covered in this part; the other linings are covered in the remaining parts of this standard.

0.3 Lead is extensively used in chemical plant construction for its corrosion resistance to a wide range of corrosive media and for the ease with which it can be worked and welded. It is more often used in the form of lining due to mechanical considerations. Most of the equipment is fashioned from sheet and pipe.

0.4 Lead can be deposited on the substrate by electrolytic deposition sprayed on, applied as a sheet lining or as a homogeneous lead lining in which a sheet of lead is homogeneously and continuously bonded to the base metal. The electrolytically-deposited and sprayed-on coatings are not recommended for the type of attack experienced in chemical industry.

0.5 Sheet linings can be applied to vessels of steel, wood, brick or concrete construction, homogeneous linings can be bonded to mild steel, copper or other metallic surfaces provided that the surface is suitably prepared. For lead pipes over 150 mm diameter the lining is often of sheet lead formed and welded to a suitable size.

0.6 It is desirable that early consultation and exchange of information should take place between the lining contractor and all parties concerned in the design, manufacture, erection and use of vessels. Appendix A gives details of information to be exchanged at this stage.

0.7 In the preparation of this standard, considerable assistance has been derived from B.S. CP 3003 : Part 3 : 1965 'Lining of vessels and equipment for chemical processes Part 3, Lead' issued by the British Standards Institution.

0.8 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part III) lays down recommendation on the design of vessels for lead linings, methods of application of linings, inspection and testing.

1.1.1 This standard does not cover sprayed-on or electrolytically-deposited lead coatings.

2. DESIGN OF VESSELS AND EQUIPMENT

2.1 General Design Considerations — For designing vessels for subsequent lining, the following precautions should be observed, as their non-observance may lead to early failure of the lining:

a) Branches and openings should be so positioned and proportioned that local stresses in the lining are avoided;

b) Supports (*see* **3.7**) should be evenly spaced and should be adequate in number;

c) As far as possible, care should be taken that side branches and other openings do not interfere with the uniform spacing of the supports; and

d) The design should be such as to minimize the possibilities of vibration, and atmospheric and external corrosion.

2.2 Metal Vessels and Equipment

2.2.1 *General* — Metal vessels should be fabricated and tested in accordance with recognized standards of good design and practice. For guidance on these requirements reference may be made to IS : 2825-1969† and IS : 803-1962‡.

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*Rules for rounding off numerical values (*revised*).

†Code for unfired pressure vessels (*under print*).

‡Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks.

Metal vessels should be of butt-welded construction, finished smooth and free from scale. In riveted construction, all rivets should be tight fitting and all internal heads and closures countersunk and finished flush with the adjacent surface and free from undercutting and crevices. The use of ribs, stays, tiebars, baffle, weirs and similar projections should be avoided; where these must be fitted, care should be taken that they are so designed and positioned that they can be fully covered with lead. The wall thickness of metal vessels should normally be not less than 5 mm

2.2.2 *Clad Sheets* — Lead-clad mild steel sheets can be preformed to make cylindrical or flat sided tanks. Access should be provided for sealing the lead lining after fabrication.

2.2.3 *Homogeneous Linings* — Where a vessel is to be homogeneously lined, ample working space should be provided for the lead welded over the whole area to be covered. The vessel should be designed to give the operator access to all parts of the surface and adequate ventilation should be provided during all lining operations.

The structural design of the vessel should be such that the application of heat in the lining process will not cause buckling of the shell or weakening of the welds.

Where the lining of branches or connections has to be welded to the lining of the vessel, they should be located, as far as possible, to permit welding in the flat or downhand position.

In proportioning a vessel, thought should be given to the effect of the location of branches and connections on the manoeuvrability of the vessel during the lining operation.

2.2.4 *Surface Contours* — All sharp corners and angles should be avoided, unavoidable corners formed by lap welds being filled by fillet welds finished smooth to as large a radius as practicable.

2.2.5 *Leak-Indicating Holes* — Vessels and equipment lined with sheet lead should, wherever possible, have leak-indicating holes so that any leakage of liquid behind the lead lining becomes apparent; this does not apply to vessels and equipment under pressure. In vessels with vertical sides, some holes should be at the junction of bottom and side plates, thus ensuring that any leaking liquid will drain from between the outer shell and the lining. Holes should also be provided in floor plates. Similar holes are also required in lined pipes and where lead in pipe form is to be inserted in steel on copper pipes being expanded by pressure against the outside wall.

2.2.6 *Pipe Connections* — Pipe connection to lead lined vessels should be provided by one of the methods given below:

a) Using a steel pipe and flange welded to the shell of the vessel, the lead lining being brought up through the pipe and over the face of the flange (*see* Fig. 1 and 2). This is generally the most satisfactory method for steel vessels. Before applying a sheet lining to a branch flange, the flange face should be finished flat after the lead is applied. Screwed flanges and welded-on pads should not be used.

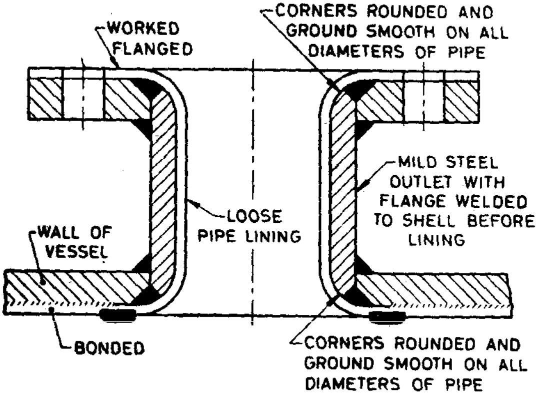
b) Welding to the lining a preformed solid lead outlet, the connection to the external pipework being then made either by:

   1) welding a pipe flange of lead without a steel backing flange (*see* Fig. 3);

   2) welding a pipe flange lead with a steel backing flange (*see* Fig. 4); or

   3) fitting a steel backing flange, well-radiused on the bore, and swaging out the end of the lead pipe (*see* Fig. 5).

NOTE — In a bottom outlet where good drainage is essential, a butt weld is preferable; alternatively, if a lap weld is chosen, there should be a recess in the vessel.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CORNERS ROUNDED AND GROUND SMOOTH ON ALL DIAMETERS OF PIPE
MILD STEEL OUTLET WITH FLANGE WELDED TO SHELL BEFORE LINING
LOOSE PIPE LINING
WALL OF VESSEL
BONDED
CORNERS ROUNDED AND GROUND SMOOTH ON ALL DIAMETERS OF PIPE

FIG. 1 LOOSE SLEEVE LINING

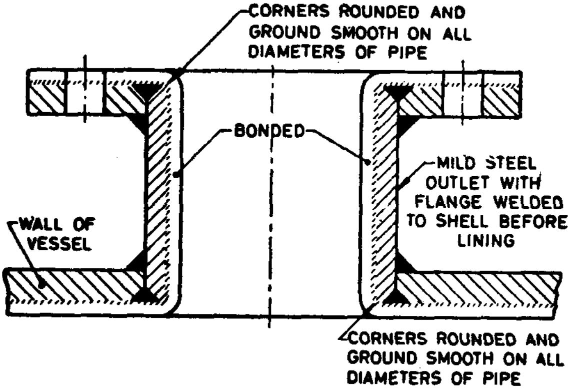
CORNERS ROUNDED AND GROUND SMOOTH ON ALL DIAMETERS OF PIPE
BONDED
MILD STEEL OUTLET WITH FLANGE WELDED TO SHELL BEFORE LINING
WALL OF VESSEL
CORNERS ROUNDED AND GROUND SMOOTH ON ALL DIAMETERS OF PIPE

FIG. 2 HOMOGENEOUSLY BONDED LINING

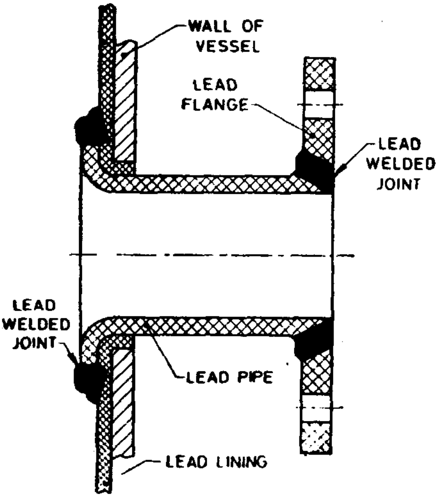

FIG. 3 OULET WITH LEAD FLANGE WITHOUT STEEL BACKING FLANGE

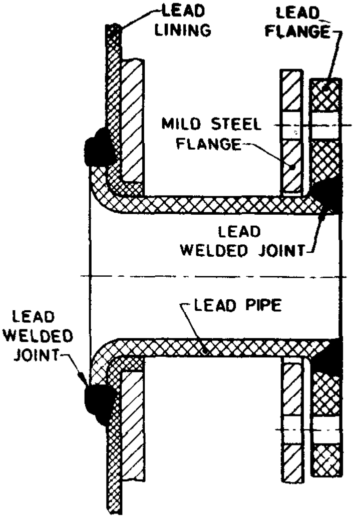

FIG. 4 OUTLET WITH LEAD FLANGE AND STEEL BACKING FLANGE

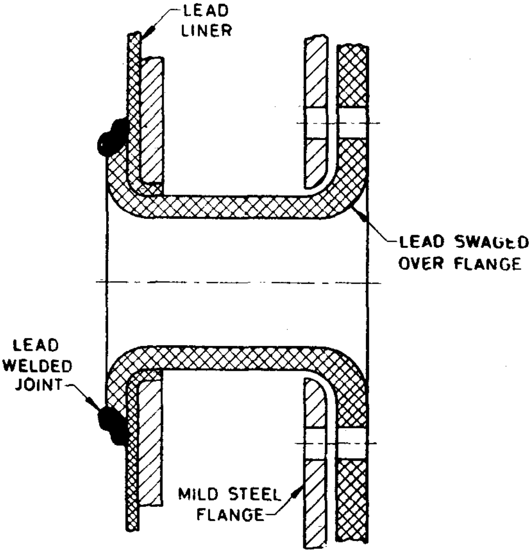

FIG. 5 OUTLET WITH LEAD SWAGED OVER BACKING FLANGE

2.3 Wooden Vessels — Wooden vessels should be constructed only from well-seasoned wood selected for its freedom from knots and shakes.

2.3.1 Corrosion of the lining may occur through contact with acidic substances liberated by the wood, particularly at elevated temperatures or high external humidity. Corrosion of this type can be prevented by applying a resistant coating to the wood or by using an interlayer of plastic sheet, asphalted felt or waterproof building paper between wood and lead.

2.3.2 Where the wood is likely to become damp, it should be treated with a preservative to protect it against fungal attack. Pressure impregnation with creosote or water-borne preservative gives maximum protection. The vessel should be supported well clear off the floor to keep it as dry as possible and to give access for inspection.

2.3.3 Mild steel tie rods and supports should be external to the vessel and protected by a sprayed lead coating, which should be painted, or by a bitumen coating. Where tie rods pass through the wood, bolt heads or nuts should be sunk into the wood so that contact cannot be made with the lead.

2.4 Concrete Vessels

2.4.1 *General* — Concrete vessels designed in accordance with IS : 3370 (Part II)-1965* are quite suitable for lead lining.

2.4.2 When the surface of lead makes contact with concrete, it should be protected by a coating of bitumen, not less than 0·25 mm thick, on the concrete in order to prevent any risk of corrosion arising from free alkalis in limes and cements. Bitumen used in contact with lead should be natural bitumen or good quality soft petroleum bitumen. Natural bitumen and asphalts composed of limestone and natural bitumen are neutral and have no effect on lead. Other bitumens or soft petroleum bitumens which are distillates of petroleum oils may be used only if they have been freed from acid, and do not contain phenol or paraffin. Where high temperatures are likely, care should be taken in the choice of bitumen. Coal tar based compositions should never be used.

Waterproof building paper or asphalted felt laid under the lead should be used whenever possible. The top edges of the tank or vessel should be radiused.

In the design of vessels partly or wholly below ground level, special attention should be given to the possibility of permeation of water or moisture. Almost all such structures are likely to be subjected to water pressure at some period of their lives and the incorporation of an impervious membrane in the structure may be necessary.

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*Code of practice for concrete structures for the storage of liquids: Part II Reinforced concrete structures.

2.4.3 *Surfaces* — Concrete surfaces should be smooth and free from surface imperfections. This may be achieved by one of the following methods:

a) By casting the concrete against specially smooth formwork and taking precautions to ensure that it is fully compacted and that no leakage of mortar takes place between the joints in the formwork. Any blow holes in the surface should be made good with a cement sand mortar (about 1 : 2) which should be carefully spread over the surface by bagging with hessian or similar material. The use of parting agents on shuttering should be avoided; but if they are unavoidable they should be approved by the lining contractor.

b) By casting the concrete against normal formwork (metal or wood) and removing surface irregularities by stoning or griding.

Alternatively, a cement and sand rendering may be applied to the structural concrete provided special care is taken to ensure that adequate adhesion between the concrete and the rendering is obtained. The rendering should be cured for a time appropriate to the cement used.

2.4.4 *Drying Out* — The concrete should be allowed to dry out naturally after the concrete and rendering have been cured. The time of drying will depend upon the actual conditions, but should not be less than 28 days for the structural concrete or 7 days for Portland cement rendering.

3. DESIGN OF LININGS

3.1 General — Lead is used for its corrosion resistance, particularly to attack by sulphuric, chromic and phosphoric acids. The corrosion resistance is largely due to the formation of a protective layer of lead salts which prevent further attack by the corrosive medium. This may be damaged by erosion, by local high chemical concentration or by high velocity impingement of stream of fluids. It may sometimes be necessary to sacrifice some corrosion resistance in favour of additional mechanical strength, by alloying the lead with other metals, such as antimony or tellurium.

3.2 Types of Lead — The types of lead covered in IS : 27-1965*, IS : 405-1961† and IS : 1654-1966‡ are used for both sheet and homogeneous linings, the choice being governed by the chemical and mechanical requirements.

3.3 Sheet Linings — Sheet linings are the cheaper form of lining and should be used whenever circumstances permit; this is the only form of lining suitable for non-metallic vessels. Sheet linings should never be used for vessels and equipment operating at pressures less than atmospheric.

3.4 Homogeneous linings can be applied only to metal vessels. Being more expensive, they are commonly employed only where conditions preclude the use of sheet linings; instances of these are:

a) where the surface to be covered is large and where it would not be practicable to provide adequate support for a sheet lining;

b) where the vessel operates at pressures below atmospheric;

c) where good heat transferer properties are important, as in steam jacketed vessels, heating coils and thermometer pockets;

d) for the prevention of creep, particularly where the vessel operates at an elevated temperature (above 150°C);

e) processes where the temperature or pressure or both fluctuate rapidly; and

f) where agitators are used or where the vessel is subject to vibration.

3.5 Thickness of Linings — The minimum thickness of lead to be used is 3·2 mm for sheet linings and 5 mm for homogeneous linings. For some processes thicker lead should be used, the appropriate thickness being agreed between user and contractor. The weight and thickness of sheet lead in general use are given in Table 1.

3.6 Factors Affecting Design of Linings — The choice of type of lead and the design of a lining will be influenced by the chemical and mechanical conditions in the plant. The following are important.

3.6.1 *Corrosion* — Care should be taken to select a lead with the desired corrosion resistance and, in design, to avoid or minimize erosion; unalloyed lead is generally most corrosion resistant but does not have such good mechanical properties as alloyed lead.

3.6.2 *Fatigue* — Fatigue failures may be due to high frequency vibrational stresses or to low frequency stresses such as those arising

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*Specification for pig lead (*second revision*).

†Specification for lead sheet (*revised*).

‡Specification for antimonial lead (*first revision*).

TABLE 1 THICKNESS AND WEIGHT OF SHEET LEAD IN GENERAL USE

(*Clause* 3.5)

Thickness mm	Corresponding Nominal Weight per Unit Area g/m^2
0·5	5·7
0·8	9·0
1·0	11·3
1·6	18·1
2·0	22·7
2·5	28·3
3·2	36·2
3·5	39·7
4·0	45·4
4·5	51·0
5·0	56·7
5·5	62·1
6·0	68·0
7·0	79·1

from alternate heating and cooling. These stresses may result in intercrystalline cracking and this is more likely with lead of coarse grain size. Such failures are likely when using alloyed B lead which has a finer grain structure and higher fatigue resistance at elevated temperatures than has unalloyed lead. Fine grain size is particularly important in welded joints, where unalloyed lead is liable to have a very coarse structure. The designer should endeavour to avoid conditions giving rise to vibration and also avoid rapid temperature fluctuations.

3.6.3 *Creep* — Creep failures are associated with the action of a static load continuously applied. Creep has been defined as the slow and progressive plastic deformation which occurs during the prolonged application of stress which, if applied for a short period, would not cause permanent deformation of the material. The coarser grained unalloyed lead may have a somewhat higher resistance to distortion under static loads, but alloyed lead has a much higher ductility and, therefore, can sustain more distortion before failure occurs, thus giving warning of impending breakdown. Unalloyed lead has low ductility under creep stress and shows little distortion before failure.

Alloyed lead containing copper and tellurium has the property of work hardening which is of value where the lining may be subject to severe local stress. Unalloyed lead does not possess this property. It should be noted that lead can creep under its own weight at normal temperatures.

3.7 Lining Supports — Adequate support of the lead lining is most important and care should be taken to secure the lead at point of concentrated stress. The positioning of supports, accessibility for the welding of the covering lead and accessibility during possible later repair should all be taken into account.

The method of supporting and the nature of the supports will depend on the size and the material of construction of the vessel to be lined, on the weight of the lead sheet and on the temperature at which the vessel will be used. Recommended methods of support are as follows.

3.7.1 *Flanged Rims* — Using the support offered by the open flanged rims of vessels, the lead sheet should be taken over the full face of the flange and secured by turning it round the outside edge of the flange (*see* Fig. 6). The lead should not be unduly thinned at this edge.

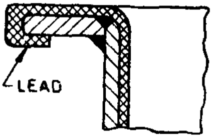

FIG. 6 LINING SUPPORTED BY FLANGED RIM

3.7.2 *Vessels Which can be Turned on Their Sides* — If it is possible to so position the vessel that patches 100 × 100 mm can be homogeneously formed on the vessel wall by downhand welding, the lining can then be welded to these patches. It is not good practice to weld homogeneous patches of lead to vertical walls.

3.7.3 *Large Areas* — A satisfactory way of supporting lead sheet over large areas is by mild steel straps, either horizontal or vertical or both, suitably positioned and spaced. If circumferential straps are used, it is necessary to consider the facilities and space available for turning the vessel to avoid overhead welds. If vertical straps are used, welds of the vertical type are necessary.

3.8 Methods of Securing Lining Supports — The recommended methods of securing the supports are as follows.

3.8.1 *All Vessels*

3.8.1.1 Where possible securing bolts should pass through the supporting strap, lead lining and shell of the vessel, the heads of the bolts being countersunk and the nuts being firmly tightened against the outer wall of the vessel, pulling the lining against the shell; the support straps and bolt heads are then completely covered by lead sheet welded to the lining sheet (*see* Fig. 7).

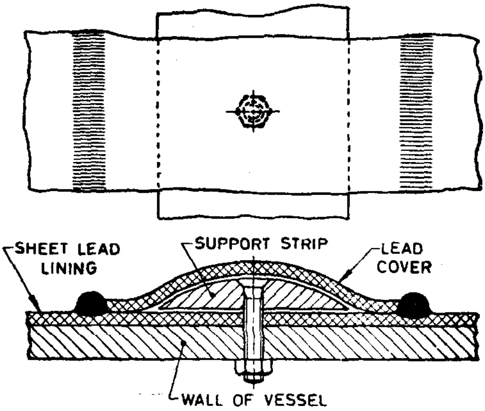

FIG. 7 SUPPORT FIXING WITH BOLTS AND STRAPS

3.8.1.2 Where it is not possible to pass a bolt through the shell of the vessel, studs should be welded to a metal vessel, and the nuts fitted inside the vessel. The supporting straps are then covered with lead as in **3.8.1.1**, lead caps being placed over the nuts and welded to the strap covering (*see* Fig. 8).

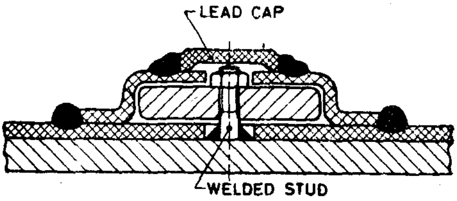

FIG. 8 SUPPORT FIXING WITH WELDED STUDS AND STRAPS

3.8.1.3 Where continuous straps cannot be used, it is permissible to use bolts, which pass through the lead lining and vessel wall, and are fitted with backing plates under the bolt heads; these are then covered with diamond shaped covering patches which are welded to the lining (*see* Fig. 9).

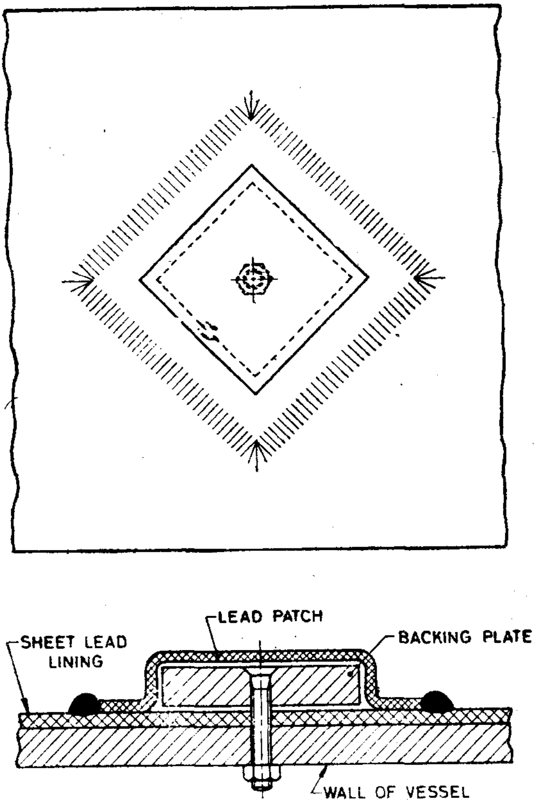

Fig. 9 Support Fixing with Bolt and Backing Plate

3.8.2 *Wooden Vessels* — The method prescribed in **3.8.1.1** can be used on wooden vessels but in this case mild steel straps are also placed on the outside of the vessel to take the pressure of the nuts.

3.8.3 *Concrete Vessels* — The method prescribed in **3.8.1.2** can be used on concrete vessels but in this case the bolt would be grouted into the vessel wall. All straps and nuts in contact with lead should have sharp corners removed, the straps should be of mild steel half round or flat section. The supporting straps should be spaced generally not more than 0·6 mm.

4. METHODS OF LINING

4.1 Sheet Linings

4.1.1 *General* — The work should be so laid out that the seams to be welded do not occur at the internal corners of tanks. A reasonable working space, at least 75 mm from the internal corner, should be provided (*see* Fig. 10). The lead should be laid to ensure a close easy fit without thinning or scoring. It is best to dress the sheet to suit the angle and then place it in position, that is, it should not be driven to the corner by tools. Only in those cases where a corner seam cannot be avoided the technique illustrated in Fig. 11 should be used.

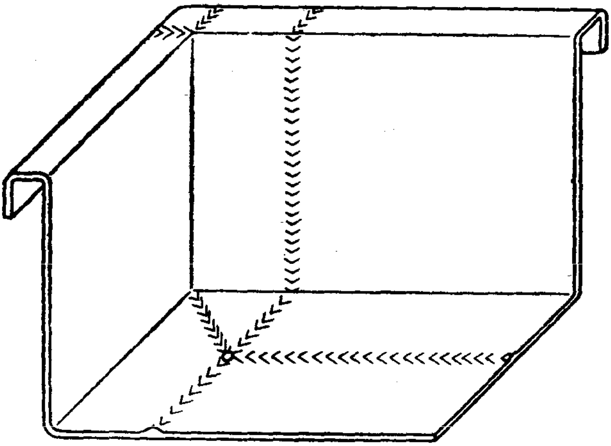

FIG. 10 WELDING OF INTERNAL SEAM

For sheet lead up to 3·2 mm in thickness, lap joints should be used, but for thickness over this, butt joints may be employed; these can be made in this thickness in a flat position or in a vertical position with the aid of a mould (*see* Fig. 12).

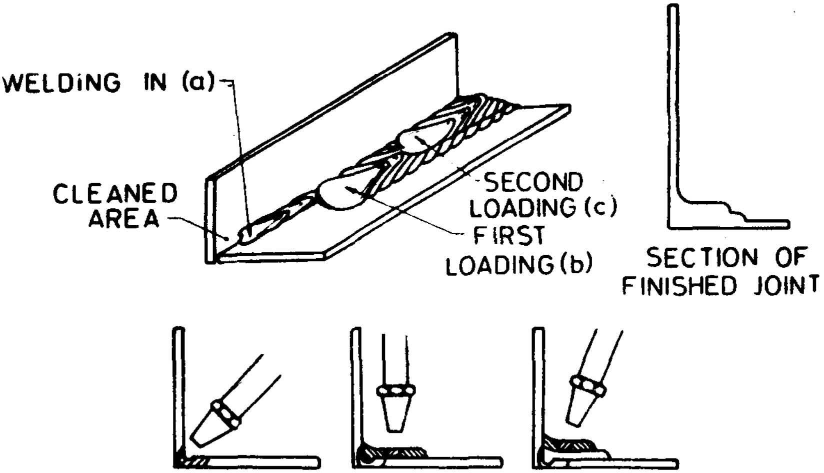

Fig. 11 Welding of Corner Seam

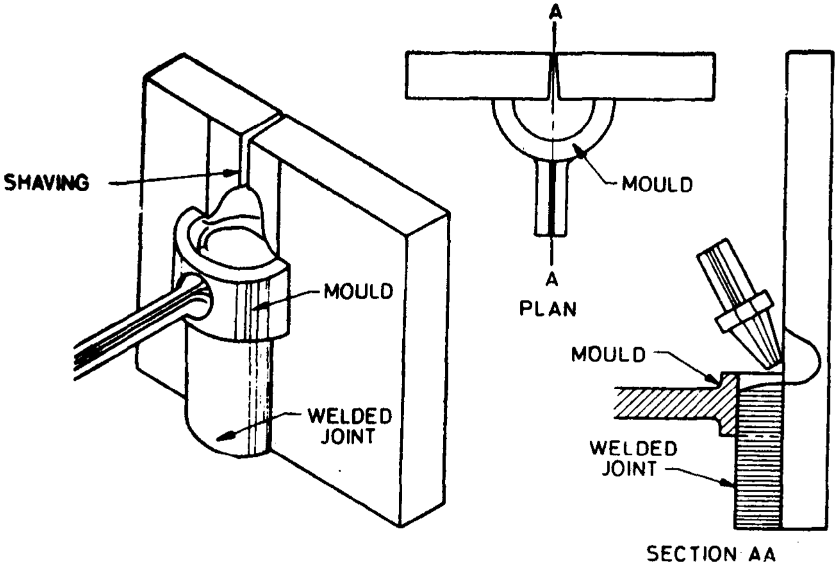

Fig. 12 Upright Seam Butt Joint with Mould Welding

4.1.2 *Preparation of the Sheet* — After the two edges have been dressed to a close fit, the meeting faces and edges should be shaved clean. For a lap joint the careful shaving of the underside meeting faces should not be overlooked. Cleanliness is essential and handling of prepared surfaces should be avoided; similarly, flux or tallow should not be used. For butt joints, with sheet lead between 3·2 and 12 mm in thickness the edges should be chamfered to give an included angle of 90°. For thickness over 12 mm the angle may be 70°, alternatively a 'U' shape can be formed, or the sheets may be laid to leave a gap of up to 6 mm.

4.1.3 *Welding* — Filler rods should always be of the the same composition as the lead which is being joined. If necessary, narrow strips cut out from the sheet may be used as filler rods. In sheet lead lining up to 3·2 mm in thickness, lap and butt joints should stand proud to the extent of 50 percent of the thickness of the sheet; over 3·2 mm, a 25 percent, excess is sufficient (*see* Fig. 13 and 14). The seams should be of even contour with a regular 'herringbone' pattern. After the welding is completed, the weld should not be shaved flat or severely hammered, light dressing only being permissible.

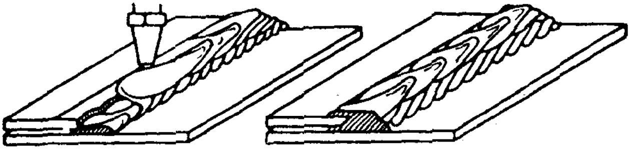

FIG. 13 FLAT SEAM JOINT

Figure 15 illustrates a butt joint of 3·2 mm and over in thickness. Each loading should be continuously fused not only to the loading below, but also to the edges of both sheets.

Where downward welds are difficult to make, such as on vertical surfaces of vessels which cannot be turned on their side, lapped upright seams should be employed on sheets up to 6 mm in thickness. The sheets should be lapped between 30 and 75 mm and the underlap should be shaved not less than of each side of the edge of the overlap. The overlap should be shaved on the edge not less than 13 mm on each face. The sheets should be kept in close contact with the edge of the overlap very slightly raised. The seam which is made without filler rod should consist of a series of small loadings melted from the edge of the overlap and fused to the underlap with the welding flame. It is essential to ensure penetration and fusion to the underlap, but at the same time

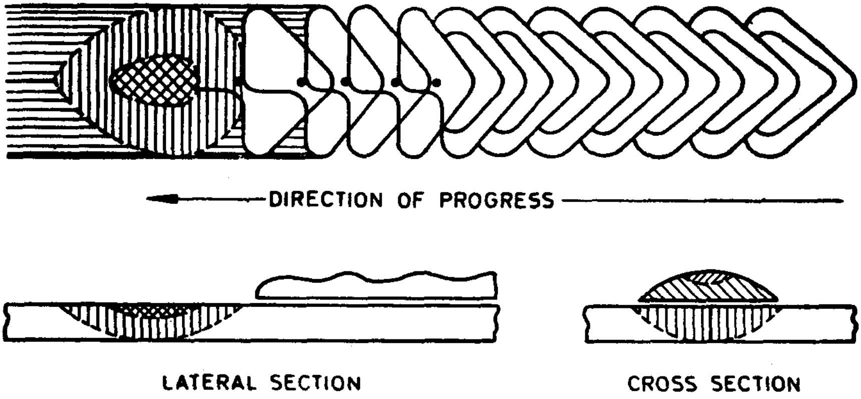

FIG. 14 FLAT SEAM BUTT JOINT

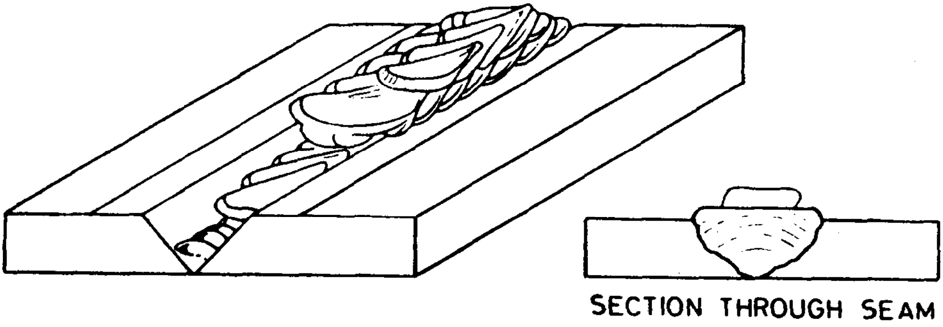

FIG. 15 FLAT BUTT SEAM WITH MEETING EDGES BEVELLED

care should be exercised to avoid reducing the thickness of the sheets by cutting in; when correctly made, these seams present loadings of equal size and thickness (*see* Fig. 16). Lap joints which change direction. for example. upright seams, are illustrated in Fig. 17.

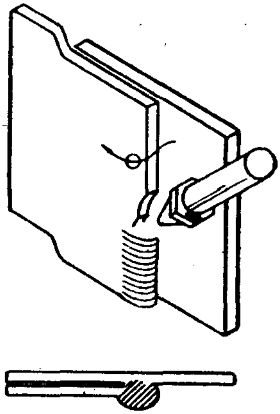

FIG. 16 UPRIGHT JOINT LAP WELD

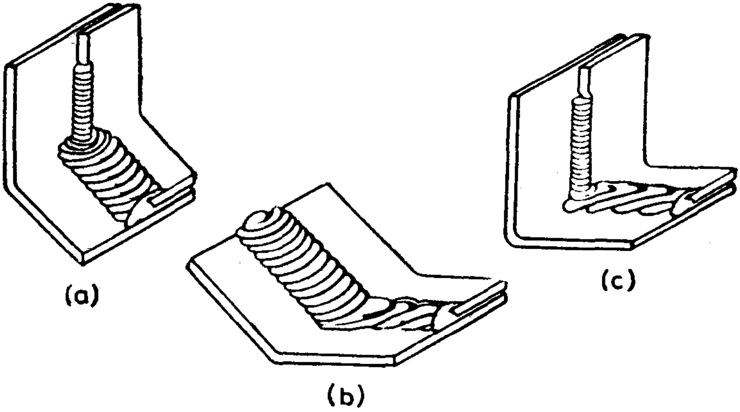

FIG. 17 LAP WELD WITH CHANGE OF DIRECTION

Vertical seams on lead thicker than 30 mm should be moulded, the finished seam being slightly less than semi-circular. This is formed by holding a mould of mild steel (the width of which is two or three times the thickness of the lead) against the face, melting the edges of the sheets and, using the welding flame, adding molten lead from a filler rod a little at a time to the molten pool contained in the mould. By moving the mould upwards from time to time so that the molten metal remains in about the same relative position, a continuous homogeneous columnar seam is formed (*see* Fig. 12).

4.2 Homogeneous Linings

4.2.1 *Nature of Lining Process* — Homogeneous linings are produced by fusing the lead to the base metal either directly or by using an intermediate layer of an alloying metal; this is usually tin or tin-lead alloy. Tin and tin alloys are not recommended where the highest corrosion-resistant properties are required, or were operating temperatures in excess of 130°C are involved. It is necessary to design the vessel for access to all parts of the surface by the end to provide adequate ventilation during fluxing operations and the application of lead.

4.2.2 *Preparation of the Surface* — Absolute cleanliness of the surface is essential and may be obtained by shot or sand blasting, grinding, or acid pickling. Crevices or cracks should be filled to avoid inclusions from subsequent processes, such as fluxing, shot or sand blasting, grinding or acid pickling.

4.2.3 *Lining of Pressure Vessels* — Where vessels of welded construction intended for a pressure test are being lined, it is advisable for the cylindrical portion to be coated before the ends (which are coated separately) are welded to the body. The deposited lead should terminate not less than 20 mm from all the welds. The vessel is then tested before the lead is deposited over the weld area to join the previously deposited lead on the body and ends.

Great care should be taken with flat surfaces so as to minimize the distortion due to local heating during the deposition process.

5. INSPECTION, TESTING, MAINTENANCE AND REPAIR

5.1 Inspection and Testing — The procedures outlined in **5.2** and **5.3** should be applied before lined vessels and equipment are put into service.

5.2 Loose Lined Vessels and Equipment

5.2.1 The lead should be tested in accordance with the procedure given in IS : 403-1964*, except where the manufacturer's certificate of analysis and test is deemed sufficient.

5.2.2 Sample should be taken to ensure that thickness or weight per square metre is within the limits agreed to between the purchaser and the supplier.

5.2.3 Visual inspection should be made to ensure that the lead is firmly against the walls of the vessels or equipment and that distortion has not occurred during welding.

5.2.4 Leaks in the lining of open top vessels or vessels and equipment which are vented to atmosphere may be detected visually by filling with water after lining and allowing to stand for 24 hours. The practice for drilling holes in the shell helps to locate faults which otherwise may not become apparent until the corrosive liquor penetrates the lining in service.

5.2.5 The practice of drilling holes in the shell cannot be applied to vessels which are to operate under pressure and the above test cannot, therefore, be applied. In such cases a dye-penetrant method of test may be applied. For this the surface of the lead is cleaned, painted with a penetrant and left for a few minutes. The penetrant is then removed by a cleaning fluid, and a developer is applied to the lining; any imperfections are then shown by blotches or lines of penetrant. Another type of indicator is one which is applied in the same manner, but imperfections are detected by ultra-violet light instead of by a developer.

Another method requires a rubber cup of suitable size, which is attached by a rubber tube to a small vacuum pump. The rim of the cup is moistened with soap solution, glycerine or other viscous liquid so that a seal is formed and the cup moved over the surface of the lead and welded seams. Where the lead is sound the cup will either collapse under suction or draw air through the sealing liquid, and leaks are found where there is no collapse or drawing-in of air.

This method is particularly suitable for testing or locating leaks in large tanks on site, such as lined brick or concrete, and should be performed before the seam has been built up above the level of adjoining lead, as the seam contour makes testing difficult.

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*Methods of chemical analysis of lead and antimonial lead (*revised*).

5.3 Homogeneous Lined Vessels and Equipment

5.3.1 *Pressure Test* — Where a pressure test is specified for homogeneous lead linings, the lined vessel should be tested in as follows:

> Where the vessel is of welded construction, the lead lining is partially completed before the ends are welded on. After the ends are welded on and before any shell or branch joints are covered with lining material, the vessel with its associated fittings are subjected to an hydraulic test of 80 percent of the test pressure. All welds in steel vessels are examined as required by the purchaser. If the welds are found satisfactory the hydraulic pressure is then raised to the specified test pressure.
> For vessels with bolted sections the hydraulic test takes place before the commencement of the lead lining.

5.3.2 *Adhesion Test* — After the completion of the lead lining, vessels should be assembled complete with any lead covered coils, agitators, dip pipes, etc.

The vessel is then filled with steam at 0·7 kgf/cm^2 gauge pressure and maintained at this pressure for one hour. The steam pressure is then released and the vessel subjected to a vacuum of 635 mmHg for one hour. The lining is then examined visually and any part of the lining which has lifted from the surface of the metal is cut out and renewed.

If any repair has been found necessary the vessel is again subjected to the adhesion test. The inspecting engineer has the right to cut into the lining to test the adhesion of the lead to the mild steel plate.

The adhesion homogeneous lead coverings and linings to copper and mild steel pipes which are to be used for heating or cooling should be tested for adhesion by bending a sample piece of pipe into a loop and visually examining the surface of the lead. The pipe may be suitably filled to prevent flattening and the bent radius should be not less than three diameters. On examination, the lead should show stress over the whole surface, the throat (in compression) exhibiting a fine textured pattern and the back (on tension) a coarser granular structure.

5.3.3 *Porosity Test* — This test is applicable only to vessels and equipment which are structurally adequate for the test. After the lead lined vessel has satisfactorily withstood the adhesion test, the vessel should be subjected to a vacuum of 635 to 710 mmHg for a period of 15 minutes; without breaking vacuum to atmosphere, steam is then admitted and maintained for one hour at 0·7 kgf/cm^2 gauge pressure. The vessel is then emptied and allowed to stand for 7 days. The lead lining should be carefully examined and should not show traces of rust.

Where the vessel is not structurally adequate for this test or as an alternative the dye penetrant method of test may be used.

5.3.4 *Test for Contamination by Tin* — Where vessels or equipment are not intended for use at temperatures in excess of 130°C, tinning is often used before homogeneous lining as a bonding agent. Where applicable and after lining is complete, a test for contamination of the lead by tin should be done. Samples of the lining should be taken by chipping out to a depth of 3·2 mm. The tin content of any sample should not exceed 0·001 percent.

5.3.5 *Thickness Test* — The thickness of the lining should be checked; this can be done quite simply by using a suitable thickness meter.

5.4 Maintenance and Repair — The repair of sheet lead lined equipment can usually be done on site by the application of patches welded on to the lining by one of the standard lead welding methods already described, the ease of on-site repair being one of the advantages of lead as a lining material.

5.4.1 Before breakdown of the lining at any particular point, it is possibe that the surrounding lead is much thinner than the original sheet. Care should, therefore, be taken that the weight of lead used for the patch is not too great otherwise the difficulty of welding thick lead to thin lead will arise. Care should be taken to use lead of the same composition as was used for the lining.

5.4.2 After the vessel has been in use it is not sufficient merely to clean the edges to be welded by shaving, as in new work. The vessel shall be cleaned out thoroughly with water or steam to remove all traces of acid. Dry powdered lime should be scrubbed over the part to be welded to neutralize any remaining acidity and to scour the surface ready for welding.

If the lining of a steel vessel is fractured, the lead should be cut at the point of fracture in the form of a cross. The corners are then turned back to expose the metal of the shell which then can be thoroughly cleaned. The lead is then pressed back to the shell, and after final cleaning the patch is applied.

Homogeneous linings should never be repaired in the vertical position, new lead being deposited in the down hand position after thorough cleaning of the base metal.

5.5 Testing of Repairs — After a repair has been completed, the vessel or equipment should be tested in accordance with **5.2** or **5.3** as appropriate.

APPENDIX A

(*Clause* 0.6)

EXCHANGE OF INFORMATION

Early consultation and exchange of information should take place between the lining contractor and all parties concerned in the design, manufacture, erection and use of the vessels and equipment to be lined. Complete and accurate scale drawings should be made available to all parties concerned.

These consultations should cover the following:

a) Site conditions as they may affect this particular work;
b) Safety measures to be taken during lining on site;
c) Construction of equipment to be lined, location of welds, joints and supports, and the compatibility of lead lining with the material of construction;
d) Nature and concentration of media for which vessel or equipment is required;
e) Operating temperatures and pressures;
f) Other factors influencing material stress, for example, expansion, vibration, or impact of contents on lining;
g) Presence of abrasives in contents, and potential local erosion by fluids;
h) Internal or external installation and means of access, lifting facilities, etc; and
j) Where necessary, the nature of the surface finish required of the lining.

(*Continued from page* 2)

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